CHAPTER 2. A CHRONOLOGY OF SURFACES, SEDIMENTS AND SOILS

INTRODUCTION

The High Plains region contains soils of many different ages, and some of the oldest soils to be found in the United States. Quaternary stratigraphy of the Southern High Plains has been reviewed by Frye and Leonard (1965, 1972), Reeves (1972, 1976), Leonard and Frye (1975) and Hawley et al. (1976). Figure 18 summarizes the general stratigraphic relationships of the major units in the uplands, and shows their relation to deposits of the study area.

In the Holocene, deposits of comparable ages have been found at the Lubbock Lake Site, Blackwater Draw and the Bailey County sandhills. Pre-Holocene Peoria (?) Loess of Reeves (1976) has been traced into the Southern High Plains but more work is needed on its character and transition into the sandhills. The loess overlies "cover sands" thought to be of Illinoian age (Frye and Leonard, 1957). Lenses of type O Pearlette ash, 0.62 m.y. old (Lava Creek B ash of Izett and Wilcox, 1982) have been found in the Tule Formation (Schultz, 1984). Thus the overlying "cover sands" must be less than 0.62 m.y. old. Reeves (1976) proposed that the "cover sands" be named the Blackwater Draw Formation. A small area of that formation has been mapped in the southern part of the study area (Eifler, 1977), but exactly what is included in that formation is not clear. Further work is needed on the relations between it and deposits of the study area.

A number of reports concern dunes in sandhills of Bailey County and adjacent counties, but the soils and their chronological relation to the dunes were not examined in detail. Tanner (1939) proposed four ages of dunes -- young, mature, old and very old. Hefley and Sidwell (1945) stated that the dunes represent at least two stages with respect to time of formation. Sanders (1951) indicated three ages of sand in the Bailey County dunes -- old, intermediate and young. Green (1951) identified four phases of sand dune activity in Lamb and Hale Counties. Jones (1959) studied two types of dunes, stable and active, in Lamb and Bailey Counties.

Nine geomorphic surfaces and associated sediments have been named in this study (figs. 2, 19). Only six surfaces are shown on the geomorphic map, but illustrations of all are given elsewhere as discussed later in this section. Longview I and II; Birdwell I and II; and Bailey I and II surfaces could not be readily distinguished and mapped without a substantial amount of detailed stratigraphic work, so they have been grouped together into Longview, Birdwell and Bailey, respectively. The mapping unit names (fig. 19) indicate the dominant surfaces present in each unit; inclusions are given in parentheses in the legend.

The sediments associated with a geomorphic surface -- that is, the sediments in which the soils have formed -- are designated by the geomorphic surface name (e.g., Muleshoe sediments; Hawley and Kottlowski, 1969). Figure 2 shows the relation of the surfaces to soil age, general morphological features and soil classification. The chronology must be considered tentative because additional sediments and soils, not yet found, may be buried in the dunes. This is particularly the case for the pre-Birdwell Pleistocene stratigraphy. Work on these sediments has been

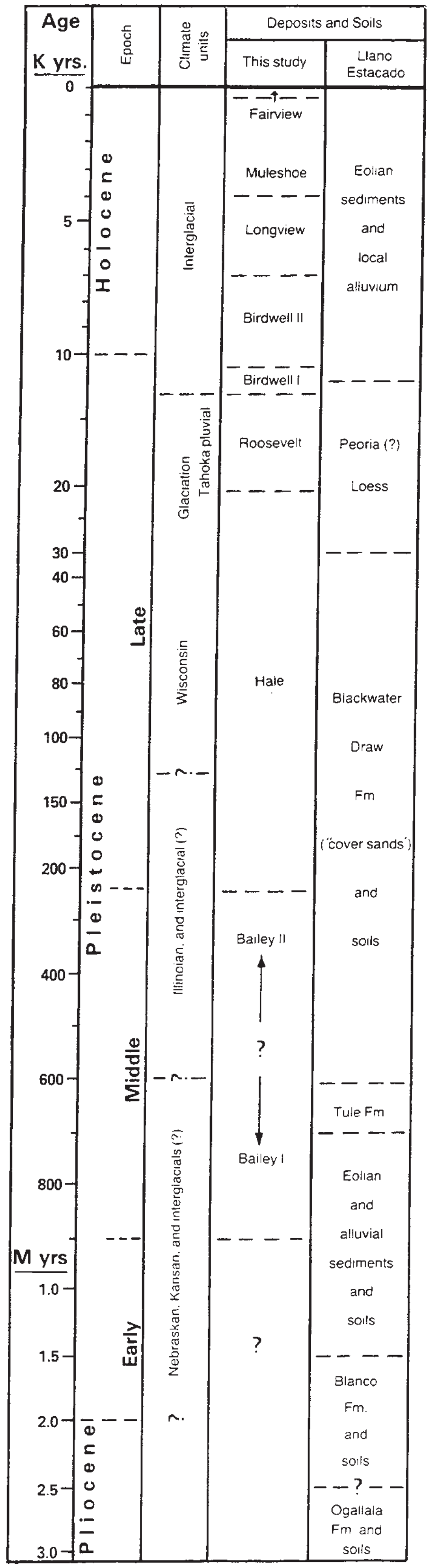


Figure 18. Diagram summarizing the chronology of upland deposits and soils of the Llano Estacado and the study area in Bailey County. Events in the Llano Estacado generalized after Hawley et al. (1976) and Reeves (1976).

Figure 19. Geomorphic map of the study area. Minor inclusions are in parenthesis. 1 = Fairview (Birdwell, Muleshoe, Hale). 2 = Muleshoe (Longview, Birdwell). 3 = Longview - Muleshoe (Birdwell, Hale). 4 = Birdwell (Longview, Hale, Roosevelt, Muleshoe). 5 = Hale (Birdwell). 6 = Bailey (Hale, Birdwell).

difficult because they are buried in most places, and some of them are very deeply buried. In addition, still older soils are thought to be buried between the oldest soils of this study (Bailey) and deposits of the ancestral Pecos-Brazos River discussed earlier.

Because of erosion and deposition in the sandhills at various intervals over a long period of time, the amounts of erosion and deposition are an important factor to consider in mapping the geomorphic surfaces. The following were used as guides for surface identification in mapping.

Concerning erosion, winds of an erosive episode can remove upper horizons or all horizons of a soil associated with an original surface. If some pedogenic evidence of the original surface remains, the surface is still identified by the same name that it has where well preserved, and erosional modification is indicated in the text. The Bailey surface, discussed later, illustrates. Where not strongly eroded, soils of the Bailey surface have argillic and thick calcic horizons. In large blowouts the argillic horizon has been swept away by wind erosion in many places. But the prominent calcic horizon remains as evidence of the ancient surface, which is therefore still identified as Bailey.

For deposition, a deposit 1 cm thick or even a few centimeters thick might be too little for practical purposes, although a deposit of any thickness may be considered significant from the standpoint of distribution and genesis of a given sediment and its effect on soil morphology. Some limit is needed because thin, discontinuous deposits of Fairview, Muleshoe and/or Longview sediments occur in important areas of pre-Longview surfaces that are so near the land surface that they should be recognized. Up to 30 cm of these younger sediments are allowed on the pre-Longview surfaces. If the deposit is more than 30 cm thick it is formally designated as the younger surface. This thickness was chosen because many Birdwell dunes have deposits up to about that thickness on their lower sides.

EPISODIC EROSION AND SURFACE STABILITY

Evidence of erosion due to man's activities is considered elsewhere in this book. But there is strong evidence of episodic erosion long before man arrived at the scene. In discussing the origin of blowout dunes Melton (1940, p. 126, 127) stated:

> If the cover of vegetation is locally killed, say at a watering place, a trail, or a farmstead, the persistent wind may scour away the underlying sand, thus exposing and killing the root systems of the anchoring grasses . . . if the climate is becoming progressively more arid, or if the groundwater surface is being lowered by other means, the vegetative cover may find itself unable to grow as rapidly as its roots are being uncovered. . . . A continuation of this process will leave a recognizable basin in the sand surface. Since the coarser sand fractions usually do not travel far, some of this sand will accumulate near the margin of the excavation on the leeward side . . . Many factors may be responsible for the development of blowout dunes in restricted localities, but in the main climatic factors seem to control the time of their development. . . . This process appears to have been cyclic, though the interval of time periods between periods of dune formation was undoubtedly irregular.

Results of this study strongly support Melton's conclusions. A substantial amount of work in various disciplines now suggests time for some of these episodes of erosion (see Climate) although the times become much less certain with increasing age. A change in climate, to a time of less effective moisture, is also thought to have been a major factor in initiating erosion and sedimentation in the southwestern United States (Haynes, 1968), and in the development of geomorphic surfaces in southern New Mexico (Hawley et al., 1976; Gile et al., 1981).

The interpretation that severe droughts caused episodes of strong erosion explains the presence of various eolian deposits in the sandhills. They should have been particularly susceptible to erosion because of abundant sand. Sandy C horizons between sets of genetic horizons demonstrate both the episodes of sedimentation and soil burial. Morphological features of the soils help to distinguish the various sediments, assist in learning details of how and where the process of erosion and deposition operated, and show how the process affected the soils.

Erosion at a particular place may continue until the climate becomes wetter, or until a resistant layer is encountered in the soil (fig. 19a). The finer-textured argillic horizons are relatively resistant to erosion, but even these can be eroded as discussed later (see also Sites 51 and 52). Prominent carbonate horizons are most resistant to erosion in the study area.

After erosion during severe drought has penetrated to or into a resistant horizon, such as an argillic horizon, sand continues to move across its top during windstorms as long as there is a source of sand (fig. 19a). When the dry climate ends, sand movement virtually ceases and thus a younger deposit comes to rest on the erosion-resistant horizon beneath (or on underlying materials if the horizon has been completely removed). If a source of sand was available throughout the history of a particular soil with an erosion-resistant horizon, a number of such episodes of erosion and burial may have occurred. But if the source area was scoured clean of sand by the end of the latest erosive episode, then the resistant horizon is not overlain by younger sediments but instead is at the land surface (see Sites 51 and 52).

Identification of buried soils in an arid region has been discussed (Gile and Hawley, 1966), and similar procedures are followed in this semiarid region. The significance of C horizons between sets of genetic horizons was noted earlier in this report; the C horizon is at the land surface in areas affected by the latest erosive episode. The underlying horizon is commonly a buried A horizon, B&Bt horizon, Bt horizon or K horizon. The contact between the C horizon and the buried horizon is commonly distinct but is less evident in some instances. If the overlying deposit is thin and is old enough to have a Bt horizon, there is no C horizon between the sets of genetic horizons; the Bt horizon of the overlying deposit rests directly on the buried horizon (see Site 43). In other cases, sediments of similar texture have been subjected to the mixing and masking processes of pedogenesis -- that is, biotic activity and movement of soil moisture (see Sites 3 and 18). The likely position of the contact, however, may be determined by lateral tracing of the overlying deposit to an area where it is thicker.

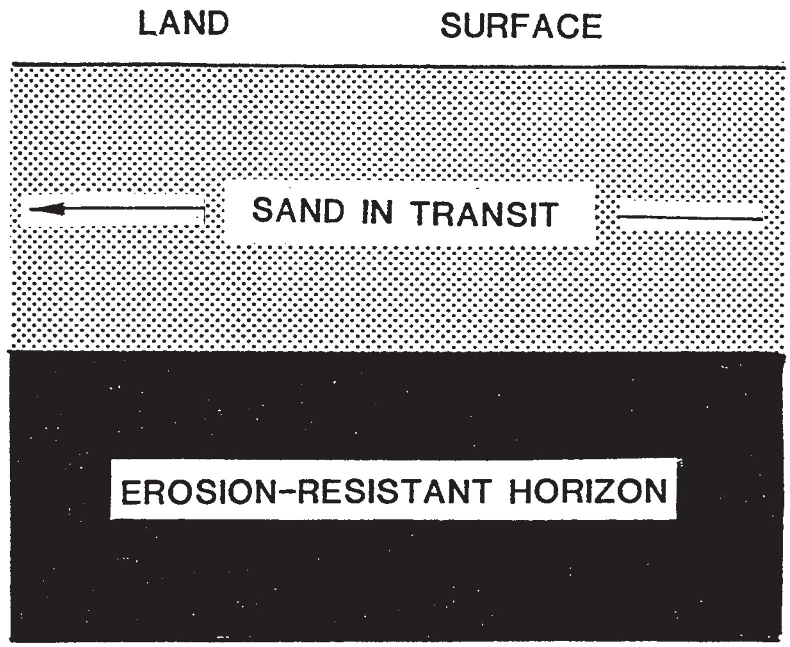


Figure 19a. Diagram showing relation between fresh sandy sediments and underlying erosion-resistant horizon. During times of severe drought, sand continues to move across the erosion-resistant horizon during windstorms as long as there is a source of sand. When the severe drought ends, sand movement stops and thus young sandy sediments come to rest on the older horizon beneath.

In some areas the sedimentary contact is illustrated in dramatic fashion. The power of sand-moving winds is suggested by the high dunes, but additional evidence is concealed beneath the deceptively smooth topography of the sandhills. Figure 17 in Gile (1981) shows sediments of Birdwell age resting abruptly on sediments of Hale age along the margine of a deep eolian groove cut in Hale sediments by strong winds in Birdwell time. Filling of such grooves may be associated with the end of the drought period and beginning of a wetter climate, when vegetation should start to grow in places that were formerly barren. The combination of more moisture and more vegetation should combine to slow erosion and deposition, and one of the effects could be the filling of eolian grooves that were cut during the period of maximum drought and erosion.

The concept of a stable surface is important in soil-geomorphic studies because surface stability controls both the character of infiltration into the soil and penetration of the wetting front. In turn, penetration of the wetting front controls the distribution of organic carbon, silicate clay and carbonate, all important components of various soils in the sandhills. The significance of surface stability has been discussed for terrains dominated by alluvial fans and fan-piedmonts (Gile et al., 1981). In these terrains, such features as landscape dissection, drainageways, slopes, and parent materials are useful in assessing landscape stability and in predicting soil occurrence. But the situation is different in the sandhills, because the process that shaped the landscape is dominantly eolian instead of alluvial, and erosive episodes of various ages have resulted in smooth slopes that do not suggest or reflect the complex soil patterns. Thus it is possible to assess surface stability and to predict soil occurrence only in very general ways. More detailed studies are required to determine the location of stable surfaces of various ages than are required in terraced terrains.

The two most important horizons in assessing surface stability in the sandhills are horizons of silicate clay and carbonate accumulation. Most of the A horizons are and were very sandy and easily removed; A horizons are missing from most land-surface soils that are older than middle Holocene. Illustrations of stable surfaces of various ages are given later in this chapter.

At stable sites, soil development is closely related to age of soil and geomorphic surface (fig. 2). After a climatically-induced time of erosion and deposition, soil development began in the newly-deposited sediments, and for this reason the age of a geomorphic surface and its soil is considered to be the same.

When the morphological range of soils on a geomorphic surface has been determined, the soils themselves can be used to identify the geomorphic surface. More time is required to determine the morphological range in the sandhills than in alluvial or glaciated terrains, because of the highly complex soil patterns in the sandhills as discussed earlier.

In many areas of the Southwest, a large number of soils can occur on a given geomorphic surface because of substantial differences in such characteristics as mineralogy and particle size (Gile and Grossman, 1979). In this study area, however, these characteristics are similar for most soils, and for this reason a relatively small number of soils occur on each geomorphic surface. On the other hand, occurrence of the surfaces, sediments and soils of the sandhills is more complex than in many terrains where soil morphology and relative age can be predicted. Thus in the stepped sequences of geomorphic surfaces in stream valleys of the Southwest, specific soils occur on specific surfaces, and the soils on progressively higher surfaces are progressively older and more complex (Gile et al., 1981). But prediction of soil occurrence based solely on landscape position cannot be made in the sandhills; soils of topographic highs may be younger, older or the same age as soils of topographic lows. This is because eolian sediments can be deposited on none, part, or all of a given locality in the sandhills during a time of climatic stress and resultant erosion and deposition. Also, smooth slopes produced by wind and colluvium can mask important boundaries between soils that differ greatly in morphology. Features useful in predicting soil occurrence in the sandhills are discussed in Chapters 5-9.

FAIRVIEW SURFACE, 1880 A.D. TO PRESENT

Sediments associated with the Fairview surface (cover, fig. 20) postdate the large-scale introduction of cattle in the middle 1880's. Fairview sediments are usually only a few centimeters thick in the study area. However, in and near the large blowout (fig. 19) they range up to about 1.5 m

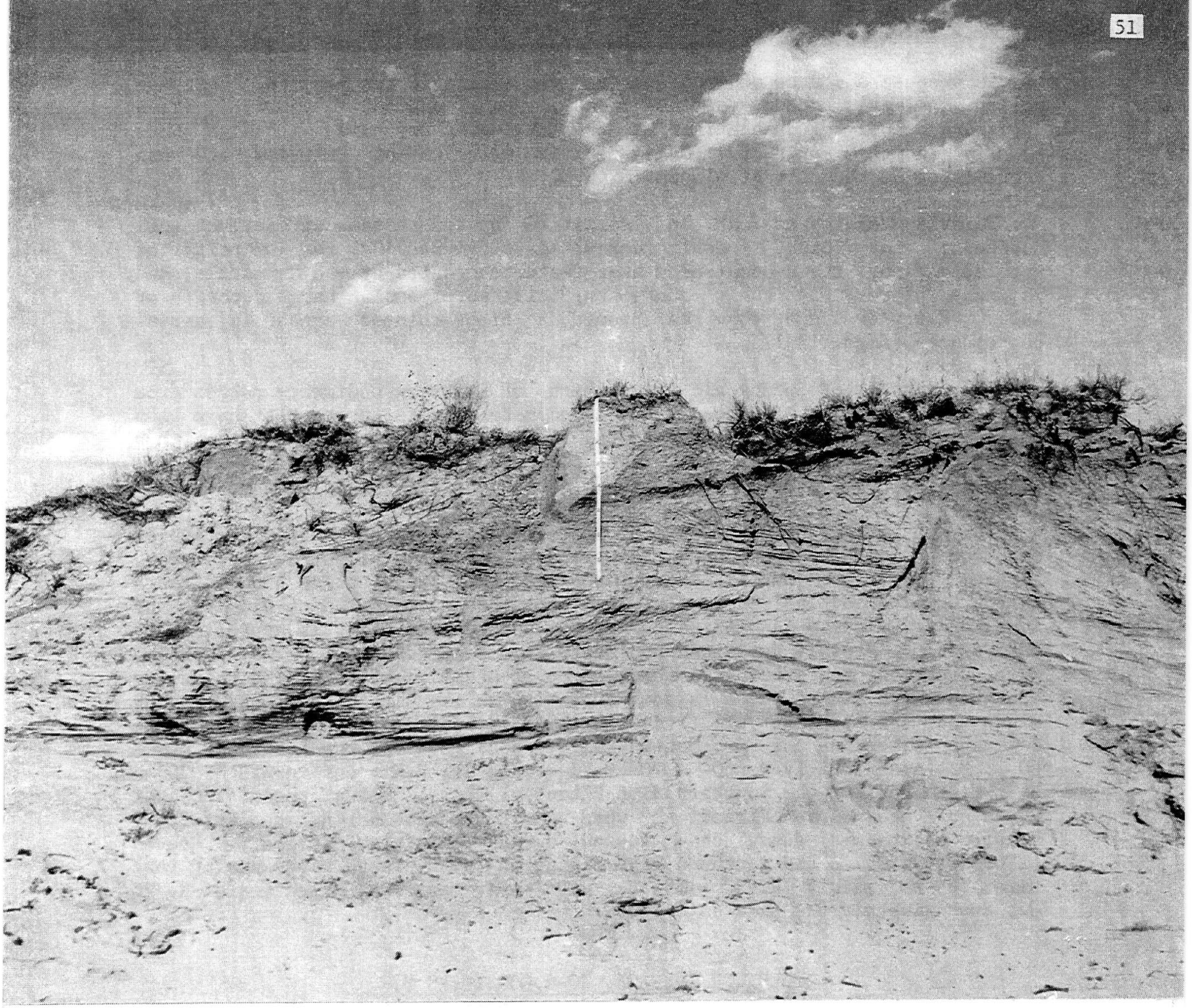


Figure 20. A closer view of the blowout exposure shown on the cover. A Typic Ustipsamment is in Fairview sediments on the dune crest, and is underlain by a buried Alfic Ustipsamment of Longview age. Fairview sediments have been eroded to the left and right of the area by the tape, furnishing sediments for younger Fairview sediments beyond. At the tape, Fairview sediments extend to a depth of about 4½ feet (1.4 m), where the dark A horizon marks the upper part of Longview sediments. See Site 1 for detail. The view is east. Scale is in feet. Photographed October 1974.

thick because a source of abundant sand was available for erosion. Fairview eolian sediments occur east of roads, fences, and active blowouts, where they are slowly accumulating at present during dry times with high winds (mostly in the spring). Gully-derived alluvium of Fairview age has accumulated at the foot of slopes (Site 37).

Fairview sediments can be identified by the absence of distinct soil horizons; in thick, freshly deposited sediments by the scarcity of vegetation; by their occurrence near features created by man or cattle; and in many places, by their sandy surficial appearance. Large deposits of later Fairview age show as prominent light-colored areas in aerial photographs (figs. 13-17).

The degree of pedogenic alteration of Fairview sediments ranges from undisturbed strata of freshly deposited materials to strata that have been partly mixed by soil fauna or roots. The sediments are so young that they do not have A horizons that are darkened throughout by organic matter, although scattered particles of organic matter are present in some cases.

In the study area there is direct evidence that the major direction of sand-moving winds has been dominantly due east for at least a few decades. Figures 13-17 are aerial photographs of the large active blowout taken during the period 1941-1981. In all 5 photographs the dominant direction of sand-moving winds, as indicated by the accumulated sand, is approximately due east. Freshly deposited sediments also occur due east of Coyote Lake, just south of the study area (back of cover and flyleaf). Elsewhere in the Southern High Plains there is some variation in the direction of sand-moving winds at the present time. Melton (1940, p. 138, 141) indicated that the dominant direction of present-day active sand movement was toward N. 40° - 50° E. and locally N. 60° - 70° E. near Clovis, N.M.; and toward N. 20° - 25° E. in most of the Southern High Plains of Texas. Melton postulated that winds of the above directions were about the same during the last 5,000 years; he termed dunes that formed during this time, Series I. Reeves (1965) working in the southern High Plains of Texas, found winds during that time to be mainly N. 5° - 35° E., with an average wind direction of N. 20° E., approximately the same as Melton.

MULESHOE SURFACE, 70-4,000 YEARS B.P.

Sediments of the Muleshoe surface (fig. 21) occur on some of the high Longview dunes, in troughs between the dunes, in scattered small blowouts, and in blowout dunes. The thick deposits of Muleshoe sediments occur only in the northern part of the study area (fig. 19).

Although Muleshoe sediments are not extensive in the study area, they are pedogenically significant because they show an intermediate stage in soil development between the youthful C horizon material of the Fairview surface and distinct profiles of the Longview surface (fig. 21). Thickness of the deposits ranges from a few cm to about 3 m. Muleshoe sediments are commonly underlain by clay band horizons of Longview age, less commonly by pre-Longview argillic horizons. The following geomorphic and pedologic evidence indicates that Muleshoe sediments are in fact a deposit younger than these underlying horizons and not genetically related to them.

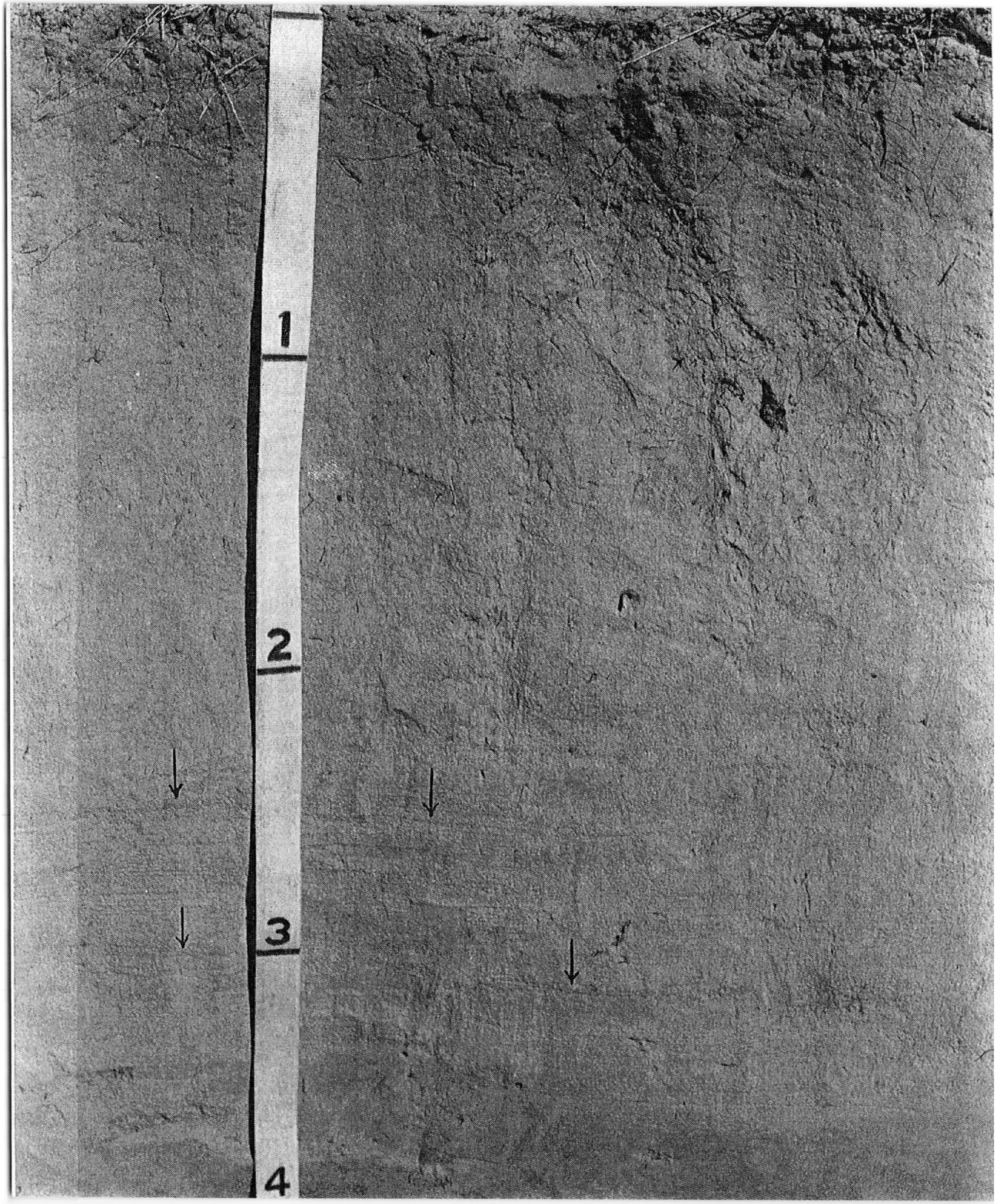


Figure 21. <u>Upper</u>. The Muleshoe surface and sediments are in the vicinity of the trench in the foreground. The light-colored sediments beyond are of Fairview age and were derived from the active blowout discussed earlier. On the skyline beyond the blowout are oak-covered ridges of the Muleshoe and Longview surfaces. The view is west. Photographed March 1977.

<u>At left</u>. The Typic Ustipsamment, Tivoli. Arrows locate occasional thin, discontinuous clay bands, which occur in some soils of Muleshoe age. Other soils of Muleshoe age have no clay bands. See Site 12 for details. Scale is in feet.

(1) Muleshoe sediments do not have the morphology of thick A1 or A2 horizons that formed at the same time as the argillic or clay band horizons beneath. Only thin A1 horizons and (in some pedons) thin A2 horizons have formed; and these horizons occur only in the upper part of the Muleshoe deposits. The A horizons are usually underlain by weak B horizons that are often slightly redder than adjacent horizons, and that in many instances show evidence of slight accumulation of silicate clay.

(2) The B horizons of Muleshoe and progressively older sediments increase in clay content with increasing age, thus are genetically related to the soil-forming factor of age and not to the horizons beneath, which must be buried.

(3) Sandy Muleshoe sediments, with the same youthful-appearing morphology described above, range widely in thickness and overlie B horizons that range widely in age (from Longview to Hale) indicating a discontinuity.

(4) In thick deposits the B horizon of Muleshoe age is underlain by C horizon material. This is conclusive evidence that the underlying argillic or clay band horizon is buried.

(5) The Muleshoe sediments are thickest near a source of relatively thick sand: the sandy A, B and C horizons of soils of Longview age. These horizons contain very little clay and silt, and should have been susceptible to erosion during severe droughts. Thus, the occurrence of Muleshoe sediments is dependent upon a source of sand for erosion, and not on the underlying horizons.

(6) Studies at Blackwater Draw (Haynes, 1975) indicate that deposits of the postulated range in age would be expected.

The likelihood that times of erosion and deposition have occurred since 4,000 B.P. in the High Plains area is indicated by Haynes (1975, p. 83):

> From 4,000 years ago to the present the stratigraphy of the Llano Estacado preserves a record of cycles of erosion, deflation and dune activity alternating with alluvial deposition and soil development, but amplitudes of the cycles did not approach those of the previous cycles, and the timing of events is obscure because of a lack of attention by geochronologists.

Although the precise age of Muleshoe sediments is not known, they are common in areas of Holocene sedimentation, and occur in the same stratigraphic position (below Fairview sediments and above Longview sediments) in both the study area and in the Coombs Ranch area near the Blackwater Draw Locality No. 1 archaeological site. At Coombs Ranch, Muleshoe sediments overlie Longview sediments that nearby have been dated with Archaic artifacts as discussed in the next section.

The contact between Muleshoe sediments and buried Longview sediments is typically characterized by the occurrence of a B or C horizon of Muleshoe age on a banded B horizon of Longview age, less commonly on an A horizon of Longview age.

Sediments of the Muleshoe surface represent the youngest of the major erosive episodes identified in the sandhills. That the episode is also the weakest is suggested by thinness of the deposits and by their relative sparcity. The time from 70 to 4,000 years ago may in fact consist of more than one change to a drier climate and associated erosive episode. This is suggested by pedogenic evidence: some soils have only C horizons beneath A1 horizons; others have weak B horizons that show evidence of very slight accumulation of silicate clay in the form of very slight reddening and/or one or several, usually discontinuous clay bands. Since the presence of more than one deposit has not been demonstrated stratigraphically, however, the sediments older than Fairview and younger than Longview have been grouped together into a single deposit, Muleshoe.

Evidence for one such change to a drier climate in Muleshoe time has been presented for about 1,000 years B.P. by Hall (1982). The change to a drier climate could have started erosion in the sandhills at places most susceptible to erosion — the sandy A horizons of the next older soils (Longview). As more resistant horizons were encountered and/or vegetation gradually adjusted to the drier climate, wind erosion may have virtually ceased. Soils with an A1 horizon, but without clay bands, could have formed in a deposit emplaced earlier in the interval from 100-4,000 years B.P.

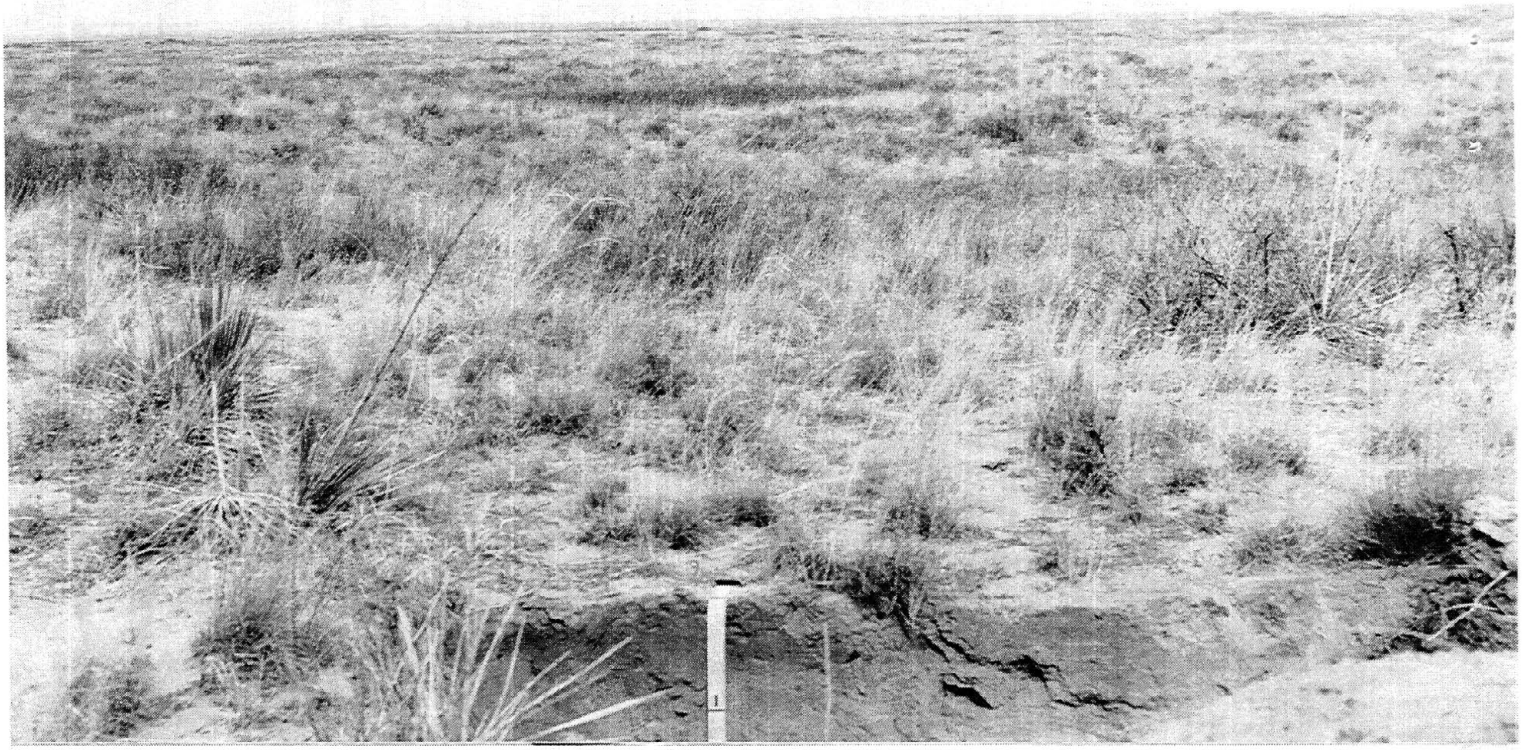
The southern boundary of Muleshoe sediments (fig. 19) is important because it also marks the boundary to older sediments dating from earliest Holocene or latest Pleistocene. South of this boundary, Muleshoe sediments occur only as thin, discontinuous deposits in scattered places such as the lee sides of ridges.

The direction of sand movement in Muleshoe time is not distinct on aerial photographs because the blowouts are small. However, the dominant direction appears to have been to the east, as indicated by field examination, because Muleshoe blowout dunes occur east of blowouts. The main body of Muleshoe sediments also extends in a general easterly direction (fig. 19). Direction of sand movement in Muleshoe time is also indicated by a broad lobe of these sediments west of the study area (front flyleaf). Both the broad lobe itself and the smaller dune forms within the lobe are headed approximately due east. A prominent belt of dune sediments also occurs due east of Coyote Lake (front flyleaf). Although these sediments were not examined, some of them may also be of Muleshoe age.

LONGVIEW SURFACE, 4,000-7,000 YEARS B.P.

Sediments of the Longview surface (fig. 22) occur in high dunes, in troughs between dunes, in blowouts and in blowout dunes. Thick deposits of Longview sediments occur only in the northern part of the study area (fig. 19). Where not eroded, soils of Longview age have A horizons and B horizons with continuous clay bands. The clay bands must have developed primarily in pre-Muleshoe time, because no difference in band morphology is apparent whether or not the soils of Longview age are buried by Muleshoe sediments. A2 horizons are distinct under oak vegetation, but are generally less prominent or absent under grass.

The soils of Longview age are very similar to dated soils with clay band horizons near Blackwater Draw Locality No. 1. At the Coombs Ranch site near Blackwater Draw, one complete Archaic point, half an Archaic point and a mano were found 10 to 15 cm below the surface of a soil with a clay band horizon (Fred Nials, personal communication). A period of widespread drought and erosion occurred on the Llano Estacado between 5,000 and 7,000



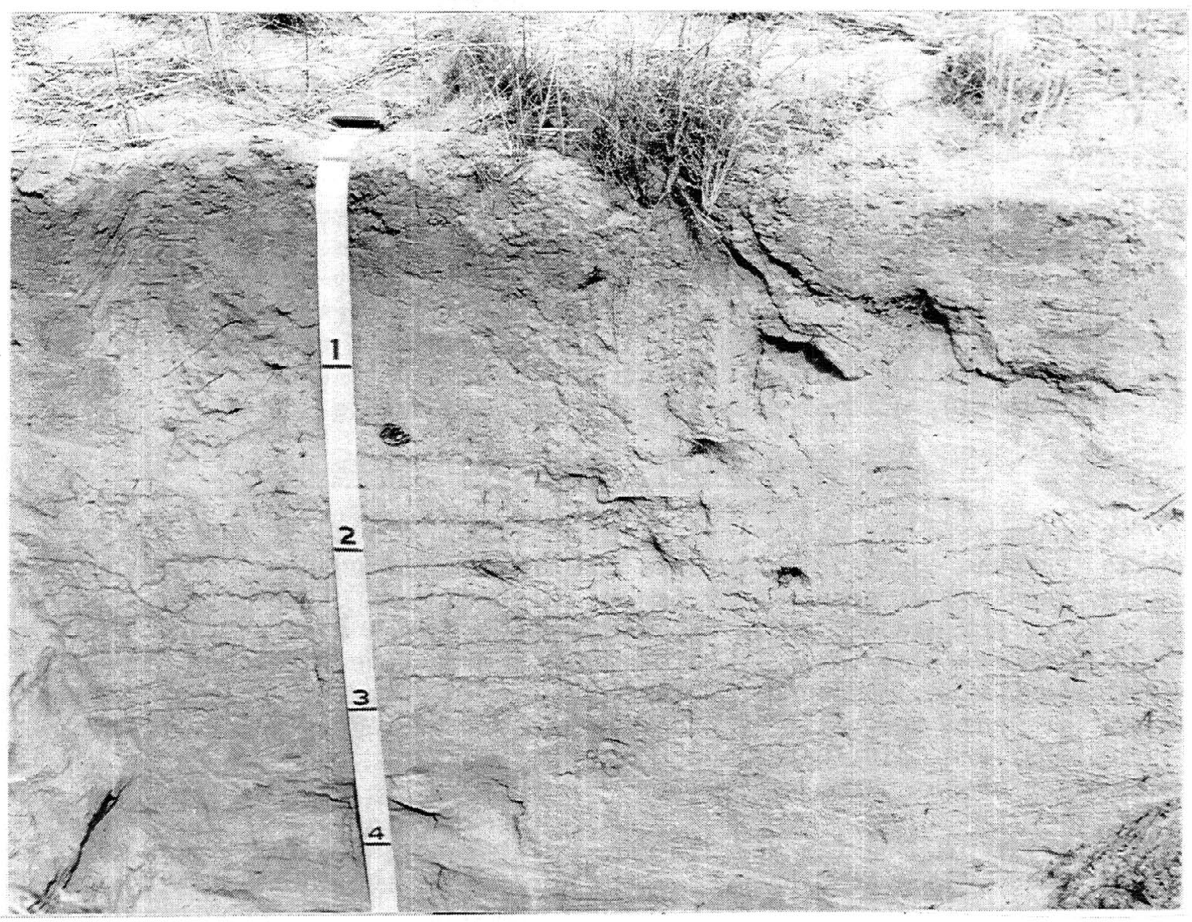


Figure 22. Upper. The foreground trench is in the Longview surface and sediments. Materials in the middle ground and on the skyline are outside the study area. The view is north. Photographed March 1976.

Lower. The Alfic Ustipsamment, Circleback, is typical of soils on the Longview surface. Clay bands are distinct and most are continuous, thus contrast with soils of the Muleshoe surface (fig. 21). See Site 19 for details. Scale is in feet.

years ago, as indicated by extensive deflation, missing sediments and lowered water tables (Haynes, 1975). Parent materials of the soil at the Coombs Ranch site were deposited during this time (Fred Nials, personal communication). Since the Archaic artifacts have an age range of 4,000 to 6,000 years B.P., the underlying clay band horizon must be at least 4,000 to 6,000 years old, but not older than about 7,000 years.

The Longview sediments range up to about 4 m in thickness, and overlie buried A horizons or buried Bt horizons. In many places Longview deposits are thick enough that the banded B horizon is underlain by C horizon material. This is conclusive evidence of a deposit younger than the underlying A or B horizons, which must be buried.

Two sediments, designated Longview I and Longview II, have been observed in thick deposits (Site 3). Longview I is buried beneath Longview II and its soil has weak A and B horizons. Longview I and II sediments may be correlative with strata 3 and 4 at the Lubbock Lake archaeological site (Holliday and Allen, in press; Holliday, 1982). Thus the Longview I sediments may have been deposited during the period from about 6,500 to 6,000 years B.P., and Longview II sediments during the period from about 5,000 to 4,500 years B.P. Holliday (1982) considers both of these periods to be times of severe drought, which reduced vegetative cover and started the erosion.

The contact between Longview I and II is distinct (Site 3), but both sediments are not always present. Formal names other than Longview I and II have not been used because identification is not always certain if both are not present. If there is no evidence indicating I or II, the soils and sediments are designated simply as Longview. Soils of Longview age that have the thickest bands are thought to represent a Longview I deposit not buried by Longview II, but this has not been demonstrated stratigraphically.

The south boundary of the main body of Longview sediments is similar to that of Muleshoe sediments (fig. 19). Only thin, isolated deposits of Longview age have been observed south of this boundary.

As in the case of the Muleshoe sediments, direction of sand-moving winds in Longview time is not distinct in aerial photographs because blowouts and blowout dunes are small. However, deposits of Longview age appear to be headed approximately due east as indicated by the position of Longview dunes, east of blowouts. Eastward-trending Longview sediments also occur in the large lobe of eolian sediments to the west as noted earlier (inside cover).

Regional significance of winds from both the west and northwest is shown by the occurrence of large eolian deposits to the east and southeast of numerous playas near the sandhills (Girdner et al., 1963). Although age of these deposits was not determined, their presence near playas over a wide area indicates significance of winds from the west and northwest.

Most of Longview time (4,000 - 7,000 years B.P.) falls within Series II time of Melton (1940) who shows Series II dunes in Bailey County as heading a few degrees north of due east (Melton, 1940, fig. 29). However, Melton (1940, p. 143) notes that "The date — 5,000 years in the past — which may divide Series II from Series I is of the most tentative nature." The change in direction from the sand-moving winds that formed analogues of Melton's

Series I dunes in the study area may actually have taken place earlier -- possibly in Birdwell time, discussed in the following section.

BIRDWELL SURFACE, 7,000-13,000 YEARS B.P

The Birdwell surface (figs. 19, 23), named in honor of Mr. J. E. Birdwell, is the most extensive surface, dominating the central and southern part of the study area. The Birdwell surface is also extensive as a buried surface in the northern part of the study area. Ubiquity of the deposits, except for blowouts of Hale and Bailey age that were swept clean by Birdwell winds, suggests the magnitude of the environmental change that took place at the end of the Tahoka pluvial.

Thickness of the deposits ranges from 1 m or less in low dunes and depressions to about 5 m in high dunes. The deposits are not as thick as might be suggested by height of some dunes because in many places the sediments were deposited on already-existing dunes. Birdwell ridges are higher in the southern part of the study area, which is near the inner Portales Valley, than they are in the northern part. The valley must have caused low water tables in pervious sediments nearby. This may have resulted in greater wind erosion and higher Birdwell dunes than in the northern part of the study area because surficial deposits in blowouts would tend to be drier if water tables were lower.

Soils of the Birdwell surface illustrate the next step in the development of clay bands and the argillic horizon (fig. 2). The Bt horizons in both Birdwell I and II sediments appear too thick and weak to have undergone deep leaching intervals such as the Tahoka pluvial. Some soils of Birdwell age also illustrate initial development of stage I carbonate in the sandhills. The carbonate horizons occur only where the Birdwell parent materials contain sand-size carbonate aggregates derived from older carbonate horizons to the windward (e.g., Site 41).

Another contrast between soils of Birdwell and pre-Birdwell age concerns the A horizon (which is still preserved in many soils of Longview and Muleshoe age) and depth to the clay band horizon. In soils of Birdwell and pre-Birdwell age, the A horizon is usually thin or absent due to strong erosion. Erosion has also brought the clay band horizon closer to the soil surface. As a result, one or more of the upper bands is commonly discontinuous and appears to be in the process of gradual disintegration by soil biota and percolating water.

The Birdwell I sediments are thought to have been deposited in the dry interval termed the Monahans Interval, from 11,000 to 13,000 years ago, at the end of the Tahoka pluvial (Haynes, 1975). The contact between Birdwell I and older sediments is the most prominent one observed in the study area and apparently reflects the magnitude of the environmental change associated with the end of the Tahoka pluvial at about 13,000 years B.P. The environmental change must have been profound indeed (Haynes, 1975, p. 83; Oldfield and Schoenwetter, 1975, p. 171). The contact is well shown at Stops 6, 7, 8, 9, and 13 along Farm Road 1731 (Gile, 1981).

The Birdwell II sediments are thought to have been deposited during an arid time in an interval designated by Haynes (1975) as extending from about 11,500 to 7,000 B.P. This may be equivalent to unit B2 in Haynes (1968) who notes (p. 607):

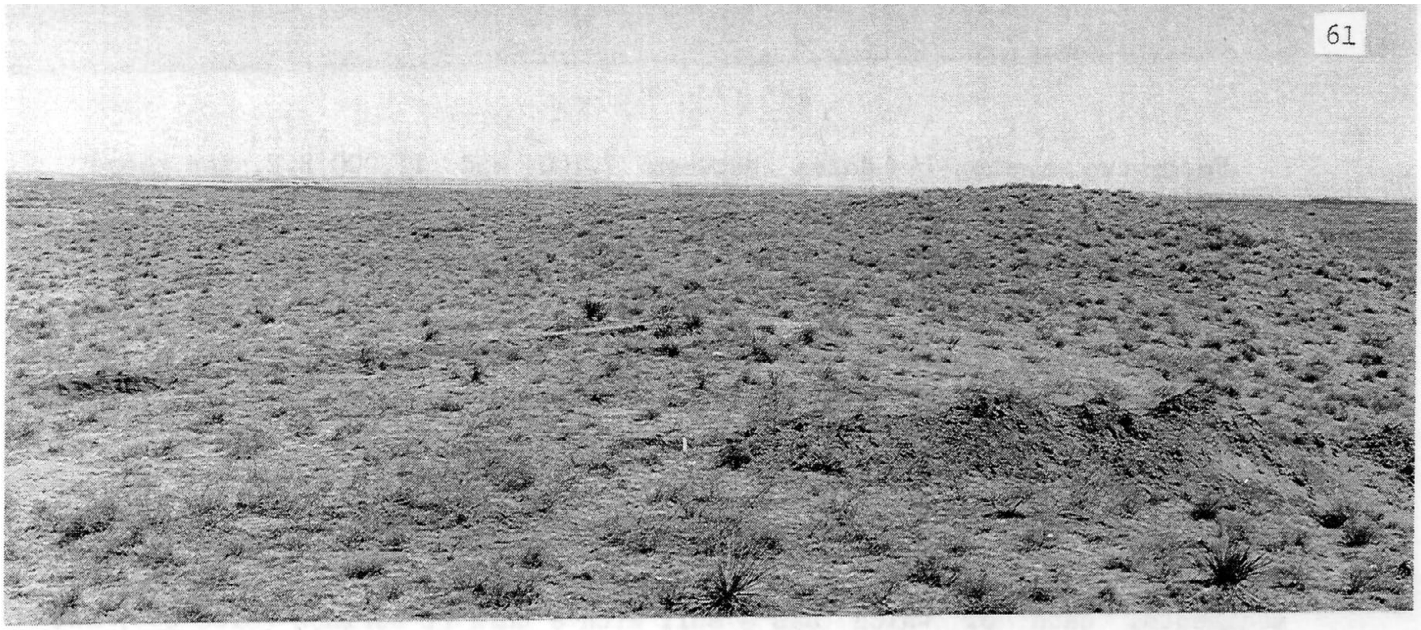


Figure 23. Above. The Birdwell surface and sediments occupy the ridge crest. The trench in the foreground locates the profile below, which occurs on the right, where the landscape changes from the level dune crest to the sloping ridge side. The view is north. Photographed March 1977.

Below. The Psammentic Haplustalf, Texico. This site illustrates a deposit of Birdwell II sediments that buries the sediments of Birdwell I. Birdwell II sediments occur to a depth of about 53 cm where they overlie the buried A horizon of Birdwell I. Sediments partly derived from the ridge side to the west have accumulated on the east-facing ridge side. See Site 38 for more detail.

> Forty-two carbon-14 dates between 7,100 and 11,000 B.P. for these cultural complexes are remarkably consistent over a wide geographic area. . . . In some dune-sand deposits of Colorado and Wyoming the occurrence of Cody artifacts . . . and Folsom artifacts . . . indicate that the deposits are eolian facies of unit B2.

The evidence suggests at least one time of erosion and sedimentation between 11,500 and 7,000 years B.P., and Birdwell II sediments may have been deposited during this interval.

As in Longview sediments, there is evidence of two different ages of materials in the span of time (post-Longview and pre-Roosevelt) occupied by Birdwell sediments; they are designated Birdwell I and II (fig. 2). The evidence consists of occasional bifurcation of Birdwell sediments into two sediments, each of which has a soil with a thin Bt horizon (Site 25); and deposition of Birdwell II sediments on lee sides of high Birdwell I dunes (Site 38, fig. 23). Two different surfaces have not been formally named because their identification as I or II is not always certain if both are not present. If there is no evidence indicating I or II, the soils and sediments are designated simply as Birdwell.

The first evidence of distinct difference from the present direction of sand-moving winds is found in dunes of Birdwell age. Pre-Birdwell dunes occur beneath Birdwell dunes, and this must be kept in mind in assessing wind direction by dune orientation. But the very size and extent of the Birdwell dunes suggests that their orientation may be a reliable indicator of wind direction. Most dunes of Birdwell age indicate directions of sand-moving winds ranging from about S. 35° E. to due east. However, linear trends in aerial photographs (fig. 19) and occasional blowouts both east and west of Farm Road 1731 suggest a time of winds from the southwest, heading in a direction of about N. 50° - 60° E. A small group of oak-covered ridges in the northwest part of the study area is heading in the same general direction; sediments of Birdwell age are known to be in at least some of these ridges, although they are buried in many places by discontinuous deposits of Longview and Muleshoe age. Reeves' (1965) wind directions for Series II dunes fall within this range of S. 35° E. to N. 50° E., and Melton's direction — a few degrees north of due east — for Series II dunes in the Bailey County sandhills (Melton, 1940, fig. 29) is about in the middle of the range.

Apparently, major changes in wind direction took place in Birdwell time — between about 7,000 and 13,000 years ago. Direction of the dune-forming winds may first have been to the southeast, then to the east and finally to the northeast. However, more work is needed on the chronology of change in wind direction.

ROOSEVELT SURFACE, 13,000 - 20,000 YEARS B.P.

A thin, but distinctive zone of materials, designated sediments of the Roosevelt surface, occurs between Birdwell and Hale sediments. Roosevelt sediments and their soils were found in a number of places by auger beneath Birdwell sediments in dunes (e.g., Sites 32 and 37), and in road cuts along Farm Road 1731 (Gile, 1981).

The Bt horizon in Roosevelt sediments is typically a fine sandy loam and grades downward into fine sand that overlies the thick Bt horizon of Hale age. It could be argued that the sand is C horizon material (of a post-Hale deposit) in which the Bt horizon formed. However, several factors suggest that the sand may represent the lower part of an A horizon on which a sandhills analogue of loess was deposited.

(1) Sedimentary strata have not been observed in the coarser material between the Roosevelt and Hale sediments. Lack of strata would agree with an A horizon interpretation since strata tend to be obliterated during pedogenesis.

(2) The coarser material overlies a thick Bt horizon of Hale age and could represent an A horizon associated with it.

(3) The Roosevelt sediments are remarkably uniform in thickness, more uniform than is generally the case for dune deposits in the sandhills.

(4) The bulk of the Roosevelt sediments contain more silt than the underlying coarser materials, and this would not conflict with an origin from a sandhills analogue of loess.

(5) Late Pleistocene loess has been extensively mapped north of the study area (Eifler, 1977). The irregular south boundary of the mapped loess is only about 25 to 30 km away.

Table 2a gives particle size data for two soils formed in Roosevelt sediments in roadcuts along Farm Road 1731, one at Stop 5 and one at Stop 7 (Gile, 1981). At stop 5, sighting from the dune west of the road indicates that Roosevelt sediments were about at the land surface on the side of the dune before Farm Road 1731 was built. Clay accumulation in a land-surface position would explain why upper horizons of Roosevelt age have more silicate clay than at stop 7 (table 2a) where Roosevelt sediments have been buried by Birdwell sediments for about 13,000 years (fig. 2). Note that all four subhorizons of the B horizon contain more silt than the A2b horizon. A sandhills analogue of loess could contain more silt than parent materials derived solely from a major erosive episode in the sandhills.

At Stop 7, sighting from the roadcut indicates that the sampled horizons at Stop 7 were overlain by about 1 m of Birdwell sediments before Farm Road 1731 was built. The upper two horizons contain less silt than the Bt subhorizons beneath. This may reflect a shift from regional deposition of a loess-analogue to local deposits derived from the sandhills.

Although Roosevelt sediments are common in dune crests beneath Birdwell sediments, they are sparse at the land surface in the study area. Apparently, as with sediments of the Hale surface to be discussed later, sediments of Roosevelt age were largely removed from interdune areas by strong erosion in Birdwell time.

The Roosevelt sediments are postulated to be correlative with Peoria (?) Loess of Frye and Leonard (1951, 1965) which they traced from Kansas into the Texas Panhandle. Peoria (?) Loess has been reported north of the area of this report (Reeves, 1972, 1976).

Age of the Roosevelt sediments may be indicated by the following. The

Table 2a. Particle size distribution for two Haplustalfs of Roosevelt age

Horizon	Depth, cm	Sand 2.0–0.05 mm	Silt 0.05–0.002 mm	Clay < 0.002 mm	Textural class
Aridic Haplustalf, Farwell 1/					
B2t	0–18	64.8	16.4	18.8	fsl
B31t	18–29	74.3	11.7	14.0	fsl
B32t	29–52	81.2	8.8	10.0	lfs
B33t	52–75	84.9	8.2	6.9	lfs
A2b	75–97	89.0	5.0	6.0	fs
Psammentic Haplustalf, Texico 2/					
A2b	0–20	94.3	2.1	3.6	fs
B1t	20–29	90.2	3.0	6.8	fs
B2tb	29–39	75.9	8.3	15.8	fsl
B31tb	39–56	82.8	7.3	9.9	lfs
B32tb	56–75	89.8	4.2	6.0	lfs
A2b2	75–86	89.9	5.1	5.0	fs

1/ Pedon at Stop 5 in Gile, 1981.

2/ Pedon at Stop 7 in Gile, 1981.

deposit would be older than about 13,000 years B.P. since it underlies the prominent contact at the base of Birdwell I sediments. In Illinois, Kleiss (1973) places the base of Peoria Loess at the Illinois River Valley bluff at 25,000 years B.P.; beyond 15 km from the valley, an age of 21,000 years B.P. was used for this base. Thus the age of basal Peoria Loess differs from one place to another. Deposition of Peoria Loess was thought to have ceased about 12,000 years ago. Kleiss (1973) also concluded that, because the latest increment of the loess is dominant, the major portion is relatively young where the loess is thin. From the above it is thought that (if the Roosevelt sediments are correlative with Peoria Loess) the bulk of the Roosevelt were emplaced within the period from about 13,000 to 20,000 years B.P. However, much more work is needed on the Peoria (?) Loess in areas adjacent to the sandhills, and the character of its transition into the sandhills.

If the Roosevelt sediments consist partly of late Pleistocene loess, it may have been deposited by northerly winds. Allen and Goss (1974), in discussing a late Pleistocene loess in the northern part of the southern High Plains, suggest that thinning of the loess southward was due to movement by northerly winds. If so, this would establish northerly winds during an interval just before erosion began in Birdwell time, discussed in the previous section. Thus some of the prominent Birdwell dunes, such as the one associated with the blowout at Site 47 (frontispiece), could have been formed by winds from northwest at the beginning of Birdwell time.

HALE SURFACE, LATE PLEISTOCENE

Only small areas of the Hale surface and its soils have been found at the surface (figs. 19, 24), but they are buried in many places. Judging from their common occurrence in buried position, Hale sediments may once have formed a thick, essentially continuous blanket over the whole area. Large blowouts now occupied by the Bailey surface may once have been covered by Hale sediments that were later blown away in Birdwell time, to form the extensive dunes of Birdwell age. Hale sediments are thin -- about 1 m or less -- in the southern part of the area but thicken considerably to the north, where they are at least 7 m thick in places (e.g., Stop 5, Gile, 1981). The Hale sediments are thought to correlate with the upper part of the Blackwater Draw Formation of Reeves (1976).

Soils of Hale age have a Bt horizon that is substantially thicker and higher in clay than in soils of Holocene age (figs. 7, 24). This is thought to be due to greater age and to increased moisture of one or more pluvials. Soils of Hale age that are at or near the land surface commonly have a filamentary stage I carbonate horizon, or are noncalcareous throughout (see Sites 33, 37a, 42, 47, and 49). Where Hale sediments are thick and deeply buried by Birdwell and Roosevelt sediments along Farm Road 1731, the soils of Hale age are noncalcareous throughout, both where the Bt horizons are underlain by C horizons (e.g., Stop 5, 1981) and by buried Bt horizons (e.g., Stop 7, Gile, 1981). This suggests Holocene emplacement of the stage I carbonate in soils of Hale age at the land surface.

If the C horizon is present, a clay band horizon commonly occurs between the thick Bt horizon and the C. After the clay bands developed, they were apparently isolated and preserved because of clay accumulation higher in the profile. The latter may be due to gradually decreasing infiltration rates caused by continued clay accumulation in the Bt horizon.

Soils of Hale age are considered to be older than about 20,000 years and to be of late Pleistocene age, a general term for the period from about 10,000 to 250,000 years ago. Although usually buried in the sandhills, soils of Hale age appear to be extensive at the surface outside the sandhills, where they are similar to Brownfield soils of the Bailey County Soil Survey (Girdner et al., 1963, p. 13).

Direction of sand-moving winds in Hale time is not apparent in the study area because Hale sediments at the surface are scarce. Examination of the Hale sediments and soils outside the sandhills might reveal the dominant direction of winds during Hale time.

A buried soil of pre-Hale, post-Bailey age was found by auger at Site 3 and along Farm Road 1731 (Gile, 1981) beneath thick deposits of Hale age and above the ancient soils of Bailey age. Observed soils of this age have Bt horizons but little or no carbonate. These sediments are not known to be at the surface anywhere in the sandhills, and are tentatively designated an early phase of Hale. More work is needed on soils and sediments in this general stratigraphic position.

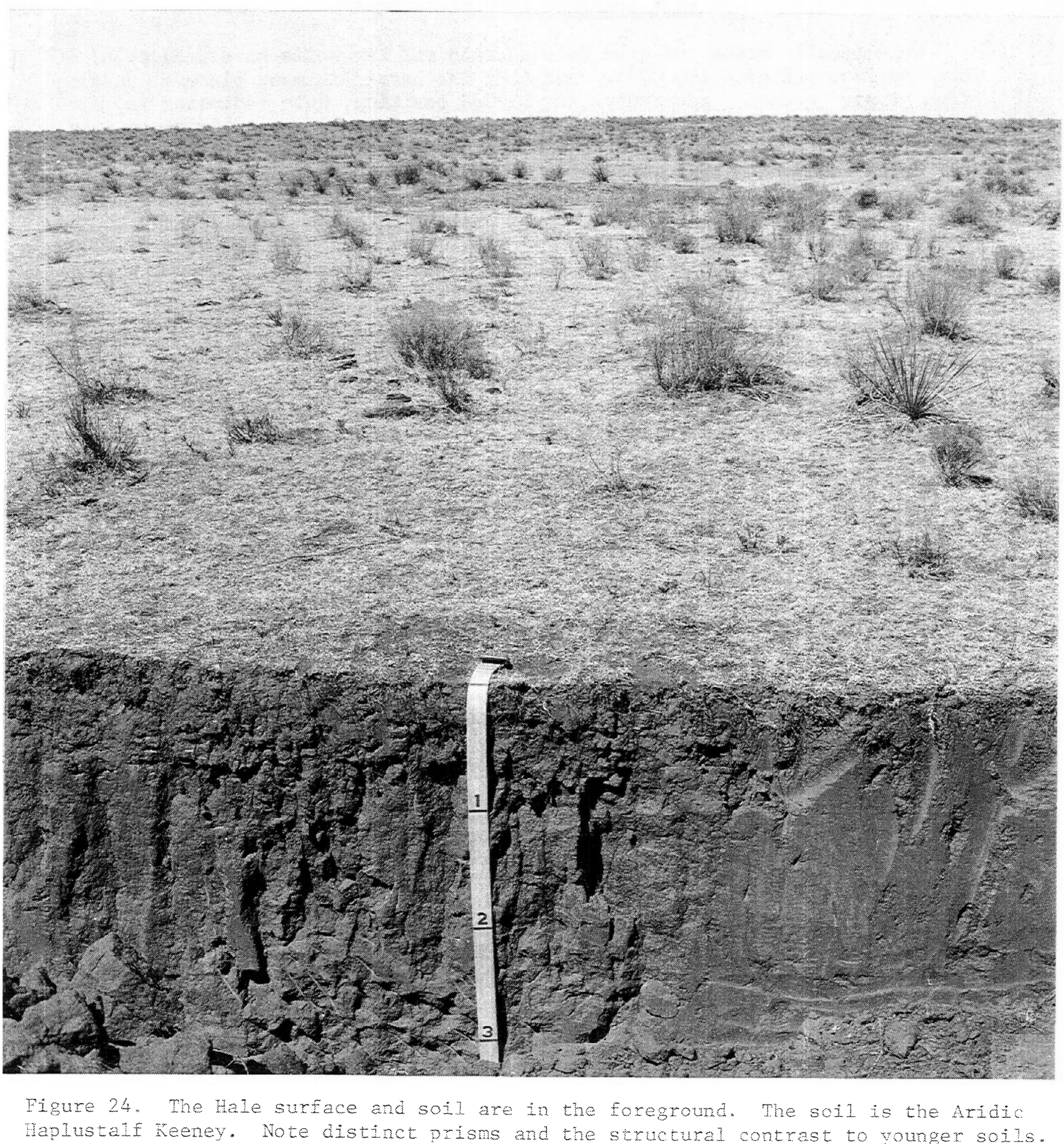


Figure 24. The Hale surface and soil are in the foreground. The soil is the Aridic Haplustalf Keeney. Note distinct prisms and the structural contrast to younger soils. See Site 49 for more detail. A Birdwell dune is on the skyline. The view is north. Scale is in feet. Photographed March 1977.

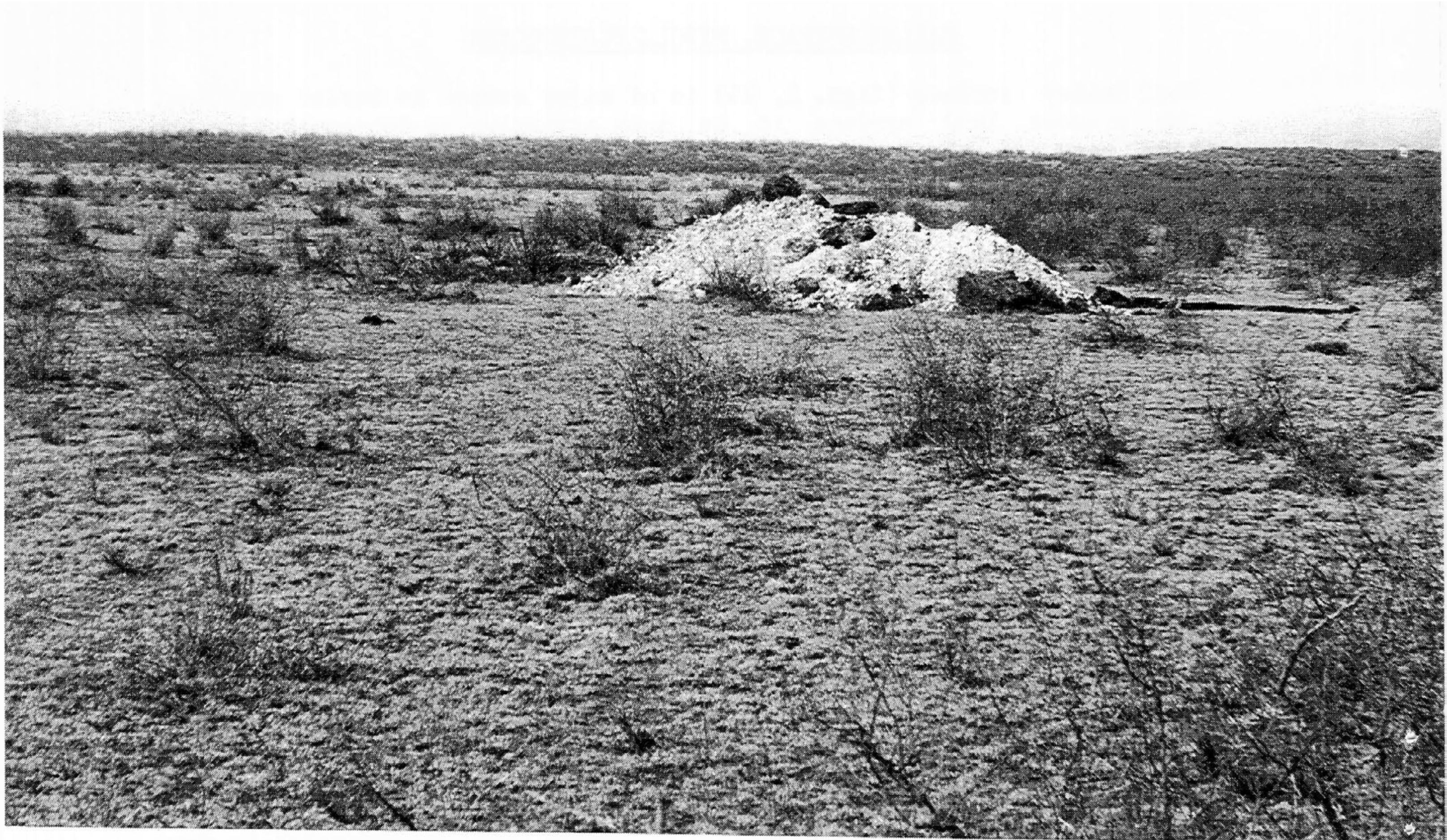
BAILEY SURFACE, MIDDLE PLEISTOCENE

The Bailey surface (figs. 2, 25) is of major extent in buried position; at the present land surface it is most extensive in depressions in the southern part of the study area (fig. 19). In the northern part, these ancient sediments and soils are deeply buried by Hale and post-Hale sediments except at Site 15.

Soils of the Bailey surface have a prominent calcic horizon, and in places an argillic horizon is also present. Few examples of well-preserved soils are known because of strong erosion at various times since the soils started to form. The thick calcic horizon is the best chronological marker because it is deeper in the soil and more resistant to erosion than the overlying argillic horizon. The calcic horizon is thicker and contains more carbonate in soils of Bailey I than in soils of Bailey II. Soils of Bailey II age have been identified in only one area, at Site 53 and vicinity. More work is needed on the relationships between Hale, Bailey II and Bailey I sediments. If there is no evidence indicating I or II, the soils and sediments are designated simply as Bailey.

The age of Bailey sediments is known only in a very general way. They are considered to be of middle Pleistocene age, and to have been emplaced between about 250,000 and 900,000 years ago. Even the older of the two sediments - Bailey I - may fall within the time span of the Blackwater Draw Formation (Reeves, 1976), and if so, Bailey sediments could be less than about 600,000 years old as discussed earlier. Until the stratigraphic relationships can be determined, however, the Bailey sediments as a whole are tentatively placed within the broader age bracket of the middle Pleistocene. Distinct dunes developed in Bailey time, as indicated by dune form of land-surface and buried sediments and soils of Bailey age (Gile, 1981, Stops 10-13).

The westernmost of the two areas of the Bailey surface (fig. 19) was mapped as the Ogallala Formation of Pliocene age by Eifler (1977). Since the sediments concerned are not Ogallala, the delineation may represent one of the inclusions of Pleistocene caliche mentioned in the legend (Eifler, 1977). But the bulk of Pleistocene time occurs between the Ogallala Formation and the Blackwater Draw Formation, which is the oldest Pleistocene unit mapped by Eifler (1977). Clearly, more work is needed on this aspect of the stratigraphy. More work is also needed to establish the relation of the Bailey sediments to the Blackwater Draw Formation.



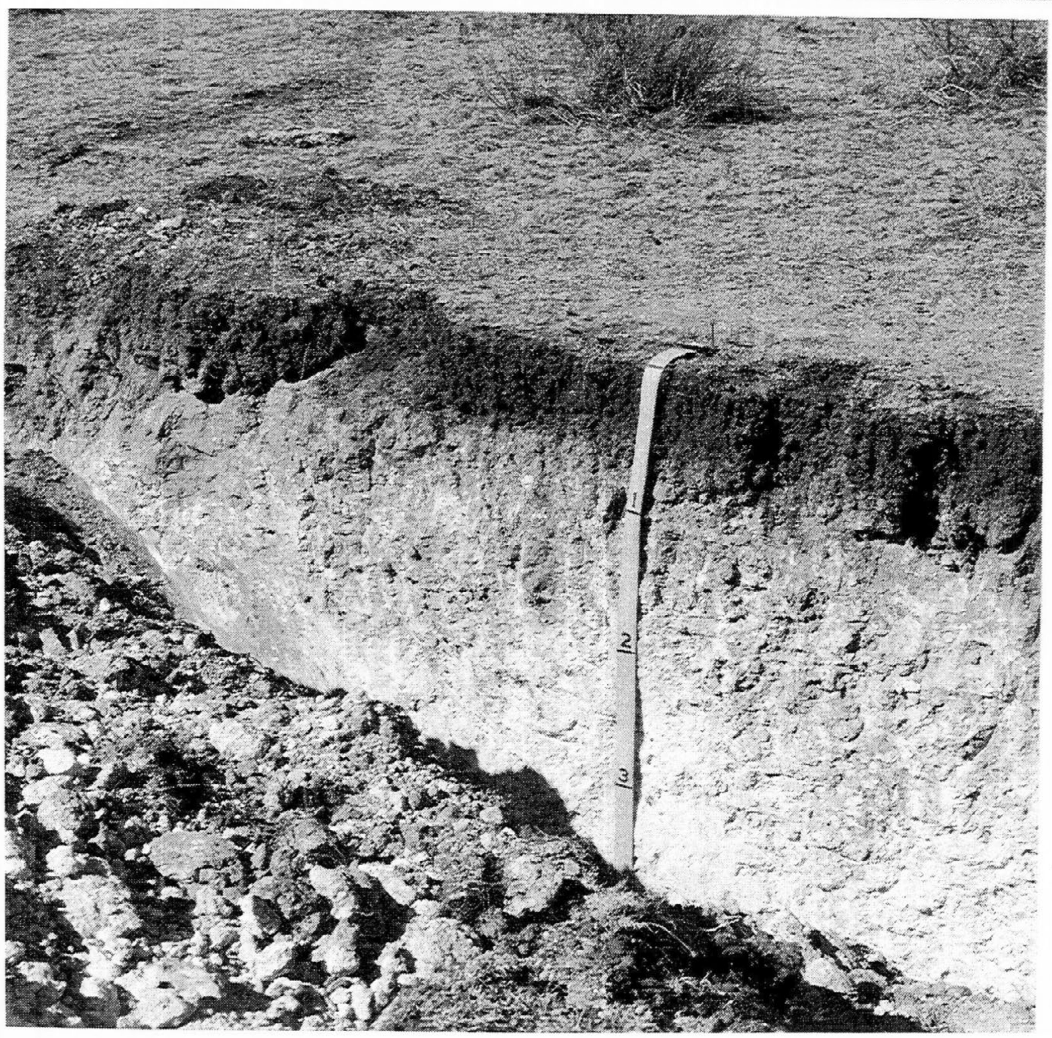


Figure 25. Upper. The trench is in the Bailey surface and sediments. A Birdwell ridge is on the skyline. The view is north. Photographed March, 1977.

At left. The Aridic Argiustoll Newell, calcic variant. The prominent carbonate horizon is typical in soils of Bailey age. See Site 50 for details. Scale is in feet.